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Structure Design and Service Performance Study of Low Wind-pressure Conductor

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Abstract. The low wind-pressure conductor is a dedicated conductor which obtains low wind resistance coefficient by changing the sectional shape of the conductor and has extensive application prospect in electric power transmission lines in strong wind areas. Previous wind tunnel testing results showed that the wind resistance coefficient in unit length of the low wind-pressure aluminium conductor steel reinforced was obviously lower than that of the conventional aluminium conductor steel reinforced, and the control factors of manufacturing process of the low wind-pressure conductor were proposed. In this paper, the low wind-pressure aluminium conductor steel reinforced JLX1/G1A(DFY)-680/45-338 was designed based on the structure optimization of the conventional aluminium conductor steel reinforced JL/G1A-630/45-45/7, and the service performance study of the conductor was carried out. Results showed that the mechanical properties, electrical properties and construction properties of the low wind-pressure conductor fully satisfied service requirements, and the conductor can be popularized and applied for transmission lines in strong wind areas.

1 Introduction

Different types of static or dynamic response will occur on the conductor under wind excitation conditions [1]. Since the 21st century, with the rapid enlargement of power grid scale and continuous evolution of climate and environment in our country, wind-induced disasters of the conductors become more serious. The typical disasters caused by wind on the conductors mainly include breeze vibration, windage yaw, gallop and subspan oscillation. Statistic data indicate that destructions caused by wind load occurred in nearly one thousand electric power transmission lines in our country in recent years, which resulted in serious economic losses and social influence. Furthermore, with the development of west to east power transmission strategy in our country, more transmission lines pass through the strong wind areas in the north-western region. The strong wind environment in the north-western region proposes higher requirements on the operational safety and reliability of transmission lines, especially Xinjiang, Gansu and Ningxia Province, in which the duration of strong wind is long and the wind speed is even and stable. The operation experience of existed transmission lines shows that the breeze vibration duration of conductors is longer, the vibration amplitude is stronger and the frequency range is wider under continuous strong wind conditions in the north-western region, and the windage yaw and subspan oscillation also frequently occur.

Vast investment is often required to realize the purpose of withstanding wind load only by improving the structure strength of conductors under strong wind conditions, and the wind load withstanding effect has certain limitation. In contrast to this, developing low wind-pressure conductors based on structure optimization of conventional conductors is an effective way to realize wind load reduction, which has brilliant application prospect. In addition, the popularization and application of low wind-pressure conductors in the regular region can substantially reduce the design load of conductor structure and consequently save the construction investment, which can realize enormous economic benefit.

Early in the 1970s, researchers in Japan began to study the low wind-pressure conductors. Some testing results were obtained, but associated research achievements were rarely applied in practical engineering. From the 1990s, Japanese researchers continued to conduct further study of low wind-pressure conductors and obtained obvious advancement in mechanism study of wind-pressure reduction and practical application of low wind-pressure conductors [2]. In this paper, the service performance study of low wind-pressure conductors was carried out, aiming to promote the application of low wind-pressure conductors for transmission lines in strong wind areas.

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2 Structure design of low wind-pressure conductor

During conductor design, the reducing effect of wind load and the constructability and corona characteristics of conductors should be comprehensively considered. In this paper, the design work was carried out based on the structure optimization of the conventional aluminium conductor steel reinforced JL/G1A-630/45-45/7, and the low wind-pressure aluminium conductor steel reinforced JLX1/G1A(DFY)-630/45-338 was consequently obtained. Structures of the above two conductors are shown in Figure 1, and technical parameters are listed in Table 1.

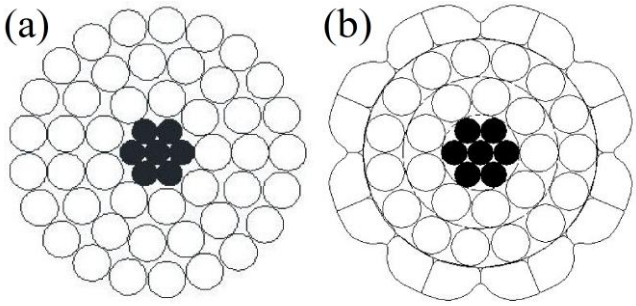

Figure 1. Structures of conductors: (a) Conventional aluminium conductor steel reinforced JL/G1A-630/45-45/7 and (b) low wind-pressure aluminium conductor steel reinforced JLX1/G1A(DFY)-630/45-338.

Table 1. Technical parameters of conductors.

Item name	Item content	
Conductor mould	JL/G1A-630/45-45/7	JLX1/G1A(DFY)-630/45-338
Conductor name	Aluminium conductor steel reinforced	Low wind-pressure aluminium conductor steel reinforced
Strand number/diameter of single aluminium wire (piece/mm)	45/4.22	45/4.22
Strand number/diameter of galvanized steel wire (piece/mm)	7/2.81	7/2.81
Sectional area of conductor (mm^2)	674.00	727.52
Outer diameter (mm)	33.80	33.75
Quality in unit length (kg/km)	2079.20	2235.44
Rated tensile force (kN)	≥150.45	≥151.00
Elastic module of conductor (GPa)	63.0	63.6
Thermal expansion coefficient of conductor (10^{-6}/°C)	20.9×10^{-6}	20.9×10^{-6}
DC resistance at 20 °C (Ω/km)	≤0.0459	≤0.0423

3 Tensile strength of single aluminium wires

Figure 2 shows the tensile strength curves of single aluminium wires of the conventional conductor and the low wind-pressure conductor after twisting. It can be seen from the figure that the change rate of tensile strength for these two conductors ranged between -6.96 % and 9.61 %. The numerical dispersion of tensile strength was small, implying that the manufacturing and twisting processes of these two conductors were controlled well. The average value of tensile strength for the conventional conductor after twisting was 191 MPa, and the value specified in technical documents was 150.45 MPa. The average value of tensile strength for the low wind-pressure conductor after twisting was 189 MPa, and the value specified in technical documents was 151 MPa. It can be found that the average values of tensile strength of single aluminium wires for these two conductors after twisting were close to each other and both of them were higher than the value specified in technical documents, indicating that the tensile strength of single aluminium wires for these two conductors satisfied service requirements.

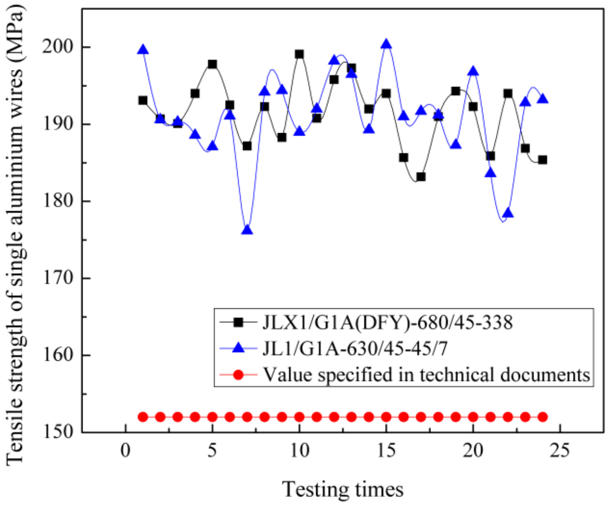

Figure 2. Tensile strength curves of single aluminium wires of the conventional conductor and the low wind-pressure conductor after twisting.

4 Vibration fatigue performance of low wind-pressure conductor

The vibration fatigue test of the low wind-pressure conductor was carried out according to enterprise standard Q/FSDYS 007-2007 'Vibration fatigue testing method of overhead conductors', and the testing tension applied to the conductor was 25 %RTS.

Figure 3. Arrangement of the vibration fatigue test of the low wind-pressure conductor.

During testing, opened the conductor clamp and checked the surface layer of the conductor carefully when the vibration time reached 2×10^7. Results showed that no strand breakage phenomenon was found in the surface layer of the conductor. After the vibration time of the conductor reached 3×10^7, opened the conductor clamp and peeled off the surface layer to check the inner layer of the conductor. Results showed that also no strand breakage occurred on the aluminium wires and galvanized steel wires. This indicates that the vibration fatigue performance of the low wind-pressure conductor satisfied the application requirement according to the enterprise standard.

5 Creep performance of low wind-pressure conductor

Creep test of the low wind-pressure conductor was carried out according to IEC standard 61395-1998 'Creep testing method of overhead naked conductor', and the testing duration was 1000 h. The testing tensions applied to the conductor were 15 %RTS, 25 %RTS and 40 %RTS, respectively. The creep rates and associated equations can be obtained according to testing results by numerical fitting as shown in Table 2. In the table, T means testing duration (unit in h). It can be seen from the table that the creep performance of the low wind-pressure conductor was in consistent with the service requirement in the IEC standard.

Table 2. Creep rates and associated equations of the low wind-pressure conductor.

Strain (kN)	Creep rate equation	Creep rate (%)		
		1000 hours	10 years	30 years
23.84 (15%RTS)	$0.0044T^{0.1965}$	0.0144	0.0346	0.0430
39.74 (25%RTS)	$0.0074T^{0.1957}$	0.0240	0.0575	0.0713
63.58 (40%RTS)	$0.0137T^{0.1939}$	0.0450	0.1072	0.1327

6 Corona and radio interference performance of low wind-pressure conductor

Corona and radio interference test of the low wind-pressure conductor was carried out according to national standard GB/T 2317.2-2008 'Testing method of electric power fittings Part 2: Corona and radio interference test'. One piece of the low wind-pressure conductor with the length of 12 m was prepared and one smooth grading ring with the diameter of 1.2 m was installed on each end of the conductor. For the grading rings, no visible corona can be found when the voltage was 1000 kV or below. After installing the grading rings, the conductor was installed on two strain hoisting points with nylon wires to keep horizontal. The height of the conductor above ground was 10 m.

During corona testing, first boosted the voltage until visible corona was detected by the ultraviolet imager on the conductor and maintained 5 min, and then reduced the voltage slowly until corona disappeared and also maintained 5 min. Recorded the corresponding voltage as the corona extinction voltage [3]. Repeated the above process 5 times and calculated the average value as testing results. Previous studies showed that the corona extinction voltage of the sample under positive DC voltage was higher than that of the sample under negative DC voltage [4]. Therefore, the negative DC voltage was employed during testing.

During radio interference testing, first boosted the voltage to specified value (0.9 times of the corona extinction voltage value of the smooth stainless pipe), and then determined the radio interference voltage RIV at 1 MHz generated in the testing circuit by the radio interferometer. Results of the corona and radio interference test of the low wind-pressure conductor are listed in Table 3. It can be seen from the table that all of the testing results satisfied the service requirement.

Table 3. Corona and radio interference testing results of the low wind-pressure conductor.

Test name	1st time	2nd time	3rd time	4th time	5th time
Corona voltage of smooth steel pipe (kV)	718	717	719	717	716
Corona voltage of conductor (kV)	659	653	661	659	654
Conductor value/steel pipe value	0.916	0.916	0.916	0.916	0.916
Specified value of RIV (μV)	≤1000	≤1000	≤1000	≤1000	≤1000
RIV(μV) actual measured value	645.7	645.7	645.7	645.7	645.7

7 Pulley passing performance of low wind-pressure conductor

The pulley passing test of the low wind-pressure conductor was carried out according to enterprise standard Q/FSDYS 008-2007 'Pulley passing testing method of conductors and ground wires in overhead transmission lines'. The arrangement of testing system is shown in Figure 4 and the testing parameters are listed in Table 4. The testing results are shown as follows: (1) no damage, strand looseness or bulge phenomena were observed on the surface of the conductor after passing through the pulley under the tension of 20 %RTS, (2) the average value of tensile strength of single aluminium wires was 188.1 MPa after passing through the pulley under the tension of 20 %RTS and the specified value in technical requirements was 152 MPa, indicating that the pulley passing performance of the low wind-pressure conductor satisfied the service requirement.

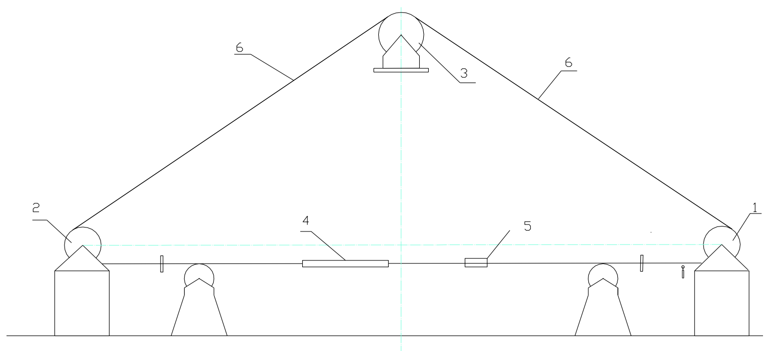

Figure 4. Arrangement of pulley passing testing system of the low wind-pressure conductor: 1-driving pulley block at the bottom, 2-driven pulley block at the bottom, 3-top pulley, 4-loading device, 5-force sensor and 6-sample conductor.

Table 4. Technical parameters of the pulley passing test of the low wind-pressure conductor.

Technical parameters	Value
Tension	30.09 kN (20 %RTS)
Wrap angle	30^{o}
Maximum distance of linear movement of steel wire	6 m
Maximum speed of linear movement of steel wire	0.5 m/s
Reciprocating times of linear movement	10 times
Diameter of pulley	0.7 m

8 Conclusions

In this paper, the low wind-pressure aluminium conductor steel reinforced JLX1/G1A(DFY)-680/45-338 was designed based on the structure optimization of the conventional aluminium conductor steel reinforced JL/G1A-630/45-45/7, and the service performance of the conductors was investigated. Conclusions can be drawn as follows:

(1) The tensile strength of single aluminium wires of the low wind-pressure conductor was close to that of the conventional conductor and satisfied service requirements.

(2) Strand breakage phenomenon did not occur on the aluminium wires and galvanized steel wires of the low wind-pressure conductor after vibration for 3×10^{7} times, which satisfied the application requirement.

(3) Both of the corona and radio interference testing results satisfied the service requirement.

(4) No damage was observed on the surface of the conductor after passing through the pulley under the tension of 20 %RTS, and the tensile strength of single aluminium wires satisfied the service requirement.

(5) All of the service performance of the low wind-pressure conductor satisfied the technical requirements, and the conductor can be popularized and applied for transmission lines in strong wind areas.

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